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## ABSTRACT

The goal of this Unesco meeting was to offer to training policy-makers, analytical tools that could help them to make the best possible forecast of higher technological manpower needs. This paper is a report of that meeting. It gives an overview of several current methods for the estimation of quantitative and qualitative technological manpower needs. The access of women to technical careers is also considered in this context. (Author/MA)

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INTERNATIONAL CONFERENCE ON THE EDUCATION  
AND TRAINING OF ENGINEERS AND TECHNICIANS

New Delhi, India, 20-26 April 1976

Quantitative and qualitative estimation of technological manpower needs

SUMMARY

This paper gives an overview of several current methods for the estimation of quantitative and qualitative technological manpower needs.

The access of women to technical careers is also considered in this context.

This report has been prepared by Unesco Secretariat in cooperation with specialized consultants.

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## INTRODUCTION

The present study does not aim at describing the well-known shortage of engineers - and maybe even more of technicians - in developing countries. Neither does it seek to discuss the over-supply of engineers or technicians in certain branches of long-established activities in industrialized countries, concurrent with lack of sufficient technological personnel in certain highly advanced industries in these same countries. We rather intend to offer to training policy-makers analytical tools that could help them to make the best possible forecast of higher technological manpower needs.

In developing countries, particularly, an adequate estimation of the qualitative and quantitative needs of engineers and technicians will facilitate the definition of the national training policy as regards such categories. Developing countries are emphasizing more and more the creation of an indigenous scientific and technological research and development capability, in contrast to the raw transfer of foreign technologies. Only such national research and development infrastructure will permit a better assimilation of imported technologies, as well as limiting the danger of their utilization without adaptation. But this infrastructure presupposes in the first place the availability of adequately trained technological manpower : engineers and technicians.

An attempt to establish priorities in the training of these two categories is perhaps to create a false problem since it is more a question of relative balance, of the proportion to be kept between these two categories both equally indispensable. Moreover, the nature of the tasks of engineers and technicians is also in evolution in developing countries. Engineers are becoming more and more responsible for the planning and design of future technologies, while technicians - which are normally more numerous and trained in a shorter time - are discharging the engineers of the immediately profitable function of maintaining day to day production. Resources being particularly limited in developing countries, and having in mind the high cost of technological training, one can see that the search of methods, on the one hand qualitative, for the identification of tasks, and on the other quantitative for the analysis of needs, could help the policy-makers of these countries to improve the economic efficiency of their development plans.

Unesco has been carrying out since 1973 experimental action whose objectives have been defined as follows :

- define starting from real situations the most appropriate methodology for the analysis of the different functions at the levels under consideration : (engineers, technologists, high technicians).
- on the basis of such analysis, to elucidate better the qualitative and quantitative needs which are to be met by technological education programmes.
- promote the international exchange of information relating these levels of education.

Parallel action is currently being undertaken particularly by the International Labour Office (ILO), by the Canadian Engineering Council and the Center for a Study and Research on Qualifications (CEREQ), France. Unesco is regularly exchanging information with such organizations.

Quantitative estimations cannot be started before a previous qualitative analysis of tasks has been carried out in order to ensure that forecasted manpower figures are meaningful. Task analysis does not seek new methods of forecasting manpower needs, but the ways of going from the usual sectorial level of global estimation to a most detailed specification of the different categories of manpower involved. For example many forecasts refer to a global need of "supervisory technical staff" which should be detailed by sub-categories of "engineers, technologists or higher technicians, technicians" and each by branch or sector of activity.

This paper ends with a reference to the discussion by the International Conference of Engineering Education (1968) of the question of access of women to higher technical education.

The paper is then divided in three main parts :

- A) Qualitative analysis
- B) Methods of quantitative estimation
- C) The access of women to higher technical education

The first two parts contain general considerations on methods of analysis while the annexes include descriptions of a qualitative analysis method and of three different methods of quantitative estimation of manpower needs followed by a bibliographical list.

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A) QUALITATIVE ANALYSIS

Considering the importance of the qualitative analysis of tasks in relation to the problems of education and of forecasting manpower needs, Unesco has developed in different countries (Hungary, Tunisia, Switzerland, Venezuela) a qualitative analysis method, designated as "Qualifications and Training Nomenclature" (NQF). This method is briefly described in Annex I.

1. AIMS

This method of analysis - "Qualifications and Training Nomenclature" or NQF as it is termed - should enable us to reply to two questions in respect of technicians, technologists and engineers.

1.1 Who does what?

Behind job titles,<sup>(\*)</sup> sometimes identical, lie different situations. Conversely, different titles cover similar jobs. This applies both at the national and the international levels. No quantitative forecasting survey is possible in the absence of prior definition of the categories involved. Comparison of results among different countries cannot be attempted if there is no common language. Lastly, fuller understanding of the scope of occupations should enable educational curricula to be improved.

1.2 How many do what?

We must know whether a job is exceptional or usual, and thus have a quantitative description of the occupational structures of an employment sector. In relation to a technology, to the form in which work is organized, and to their evolution, we must be able to estimate, and justify, the number of persons to be trained.

2. LIMITATIONS

We are not attempting, a priori, to try out or impose a new method of forecasting personnel requirements. Many exist already. On the other hand, the NQF seems, in our view, to represent a tool for penetrating analysis, linking questions of employment with those of education, designed to be used at certain clearly-defined employment or educational levels, as a supplement to existing methods and calculated to amplify their results.

2.1 Although global analysis of employment and its evolution already exists as part of national planning, there is still a need, in general, to introduce distinctions into the results of such analysis within certain sectors, which, for the sake of overall analysis, are often lumped together. Consequently, there is a need for a tool allowing of a more penetrating analysis which can be used somewhat as a magnifying glass at certain specific levels.

<sup>(\*)</sup> Job and function have been taken in the same sense in this document.

2.2 Where no planning exists at the national level (which is often the case in the developing countries), comparative studies, conducted in different countries in respect of employment structures in homogeneous occupational branches, or sections of them, in a clearly-defined technological and economic context, should allow of a perhaps rough, but rapid, evaluation of requirements at certain levels. A tool for analysis of employment structures is therefore necessary.

2.3 The NQF is able to provide a static, qualitative and quantitative picture of the labour structure in an economic sector or specific occupational branch, at a given moment and within a particular technological context. Owing to its static character, it does not in itself constitute a method of forecasting demands. It is one instrument among others intended to assist planning, as is explained in paragraphs 2.1 and 2.2 above.

2.4 Therefore we must try to improve our understanding of the evolution of possible tasks. As it is pointed out in the Introduction, similar research in this direction is being undertaken by such organizations as ILO, CEREC in France, the National Engineering Council of Canada. After this essential first stage, we must move from the static to the dynamic problem: this is the aim of quantitative estimations as presented below.

#### B) QUANTITATIVE METHODS OF EVALUATION OF NEEDS

The purpose of this is to set out the main methods used in forecasting quantitative needs for engineers and technicians.

Before embarking on a description of these methods, one should have a clear idea of the use to be made of the results obtained. Consideration and investigation of this subject are designed to throw light on two basic questions of concern to those who plan national economies, particularly those of developing countries:

- (a) the best of human resources;
- (b) educational planning.

The first question relates to one of the main objectives of any kind of economic planning. Forecasts of personnel needs presuppose that the quantities of goods and services to be produced have been previously determined, and that some idea has been formed of labour productivity. Further, technological developments and economic expansion bring about a great diversification of activities and a growing specialization in occupational structures. Thus in order to avoid a wasteful use of trained personnel it is necessary to consider in detail the various qualifications which will be required. In other words, employment policy cannot be concerned with only the present or near future, since it takes time before qualifications can be modified; forecasting methods must be directed also towards the medium - and long-term outlook, since the very structure of the educational machinery which trains personnel in the various special fields yields results only in the medium and long term.

There is no question in this paper of denying the cultural rôle of education, the final purpose of which is not merely that of meeting the economy's manpower requirements. The education system has also other functions, such as that of contributing towards the development and fulfilment of the individual and facilitating his integration into society by broadening his understanding of the technical, economic and social phenomena which affect his environment. But occupational activity takes up an important place in the life of individuals, and education, which is a training for life, must devote a substantial part of its efforts to such activity: structural changes in employment are necessarily reflected in a demand for more sophisticated and varied qualifications, with consequent repercussions on the training machinery. Hence the meeting of personnel requirements is seen to be one of the objectives of education. A comparison between the personnel requirements of the economy and training resources involves prior analysis of the causes underlying the requirements in respect of the various types of personnel. These requirements, for a given occupation (for instance that of engineer or technician), are in fact due to vacancies created by those who retire from working life coupled with variations in the number of jobs available. They are also influenced by occupational changes, which are reflected either in a change in the level of qualification, or in the choice of careers different from those for which individuals already engaged in working life were originally trained.

This comment is important when calculating requirements in respect of engineers, since after a certain stage in their career engineers employed by firms find themselves competing for senior executive, commercial and financial posts with people having a different kind of training.

1. The procedure used in forecasting

All the methods used involve, in essence, the following stages:

1. Once production targets have been established, labour productivity is projected separately for each sector, thus making it possible to estimate the total manpower needed in each sector to achieve the given level of production.
2. A projection is made, for the same period, in regard to changes identified in the occupational structure, by sectors, from which can be deduced the variations in the relative number of posts for each occupational category.
3. To the manpower needs thus obtained for each occupations are added the number of vacancies to replace those retiring from working life during the period.
4. Using a table correlating the various occupations with the training needed to follow them, personnel requirements by occupational category are then expressed as training needs by type and level of training.

As regards projections, four methods may be used, or a combination thereof. Their basic features are as follows :

1.1 Extrapolation from past trends, adjusted to a greater or lesser extent in the light of critical reflection. This is the method which is used, even intuitively, in everyday life: it is from the knowledge of what is, that one forms an opinion of what the future may be like.

This method has its uses, since it has the advantage of making one take a clear view of the present situation, and proper forecasting can only begin with a knowledge of the present, the only point in the development curve which can - and should be - known with certainty. It has however the drawback of resting on an assumption which tends not to be sufficiently checked in periods of rapid and radical change, namely that trends represent a continuous function, and that past behaviour will continue in the future. It is thus necessary to have a thorough knowledge of past behaviour, in other words have access to comparable statistical series covering long periods; but this is far from being actually the case, particularly in the developing countries.

This accounts for the use of the second method.

1.2 International comparisons. Different countries are at different stages of their economic and social development. From one's observation of countries which have reached a relatively advanced stage, it is assumed that those whose development got under way only recently will follow the same trends, though with a certain time-lag. This method has yielded good results for market research into certain products and between certain countries: for example, the market for nylon stockings or electrical household appliances in France progressed in a similar way to the market in the United States for the same products, with a certain time-lag.

As regards forecasts for personnel requirements, this method can only be used as a rough guide which it would be dangerous to follow literally. On the one hand, it is not certain, nor is it perhaps desirable, that the economies of developing countries go through the same phases as those of industrialized countries. Employment structures in these two types of countries will probably not develop in the same way, and certain intermediate stages may be "skipped" by the developing countries. In addition, while the number of engineers, to take one example, has been fairly well known for a fairly long period in the developed countries, much less is known as to the number of technicians, since this is a type of personnel which has only relatively recently been recognized as having a separate identity and originality.

These drawbacks resulted in recourse to a third method.

1.3 Finding correlations between the occupational structure and indicators of economic and technological development

The object is to elucidate the factors which govern trends in the structure of the working population by level of qualification, and to assess quantitatively the impact of each of these factors on the occupational structure. The factors most generally used are gross national products, in the aggregate or by sectors, output per worker, per capita energy consumption, and gross (fixed) capital formation per worker during the period preceding each census. Use has even been made occasionally of "non-monetary" indicators of development.

This is a method, or rather a group of methods, which is more intellectually satisfying, requiring the use of sophisticated econometric techniques and calling for a substantial volume of statistical information.

It has also the advantage of making it possible for voluntarist elements to be built into the forecasts : if there is a significant correlation between the GNP desired in five years' time and the occupational structure, the latter can be worked out, since the target GNP is known; in particular it will thus be possible to obtain an assessment of the number of engineers and technicians required to achieve the fixed target.

There is however one substantial drawback to this method: existing data are so unreliable that their use in conjunction with sophisticated methods of calculation may well give a false idea as to the value of the results : one should beware of falling under the spell of figures. It is for this reason that the fourth method, recourse to which may appear surprising to a determinist, can shed valuable light on the subject.

#### 1.4 The Delphi method

This is the systematic exploitation of the opinions and information held by a group of individuals who are interested in the subject, on the principle that "two heads are better than one". This method, based on the organization of group discussions and "brain-storming" is sufficiently well-known and will not be described in the ensuing Practical Guide.

### 2. Practical Guide

When all is said and done, the methods used for forecasting have at least served to guide forecasters in their first faltering steps, and at the same time have yielded appreciable practical results.

It is for this reason that it seems worthwhile giving a description of some of these methods on the lines of a practical guide, without going into finer details and without making any comments.

It is assumed that the reader is already sufficiently aware of the precautions to be taken in using the results obtained from the application of these methods.

The first method is a pragmatic one, which has been used particularly to determine requirements in respect of engineers and technicians. It is based on rational extrapolation from past trends, adjusted by a wide range of additional data.

The second method can be used generally for all manpower categories. It aims at obviating the drawbacks of mechanical extrapolation by distinguishing:

- (a) production by each sector as a proportion of total production;
- (b) each occupational category as a percentage of total manpower in each sector.

Lastly, the third method, a very rapid one if one knows the number of engineers and certain indicators, at specific dates, can yield an order of magnitude which is adequate for a preliminary approximation.

### 3. Towards new concepts in forecasting

In the light of the comments presented in the foregoing account on the merits, and also the inherent defects of our forecasting methods, a number of conclusions should be drawn which can be briefly listed as follows :

1. The means used represent in themselves an appreciable step in the right direction. They should be not only used but also, as far as possible, improved on.
2. Improvements imply progress in two fields: that of theory and that of information, with emphasis on the fact that theory must obviously precede data collection.
3. One has the feeling of being tied to three alternative procedures: extrapolation from past trends, international or inter-sectoral comparisons, and correlation with certain economic indicators.
4. While these approaches enable one to forecast with a greater or lesser degree of reliability, they do not afford an in-depth understanding of the phenomenon.
5. For this purpose one must go back to the general problem of the use of human labour for productive ends, and consider the meaning to be ascribed to "the needs of the economy" and "occupation".
6. The idea of "needs" is still somewhat imprecise. Setting aside the problem of the cost of labour, which pays a complex rôle in the employment market, it is frequently observed that the supply of labour influences demand: if a large number of engineers are trained, most of them will end up by working, for one employer or another.
7. A new slant is therefore being given to investigations into the inter-relationship between the educational and the socio-economic processes.
8. The most recent investigations relate to the problems of access to employment, and of settling into an occupation, through a study of labour mobility in the first few years. Interest is also coming to be attached to the classification of occupations, by type; for example, J.S. Smith distinguishes between (a);  
"bridging occupations", providing opportunities for advancement through experience;  
occupations in which the individual remains at the same level all his life;  
"preparatory occupation", leading to other occupations;  
occupations with successive steps of responsibility, as in a pyramid ("career hierarchies");  
occupations where one's responsibilities remain the same but one gets periodic salary increases ("incremental hierarchies").

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(\*) The analysis of labour mobility in manpower policy - London School of Economics, 1966.

9. Here we see the importance of techniques for observing and describing the nature of the work performed, which should go beyond the techniques of job evaluation to concentrate attention on the concept of man's action in his working environment, i.e. what best reflects his relationship with his work. Particularly for an engineer, the way in which he intervenes in the functioning of the organization for which he works sheds considerable light on the qualities he possesses, which his training and experience should be such as to confer.
10. In parallel, in order to improve forecasting methods, in-depth studies should be conducted on the various sectors of the economy and on the organization of production units, with a view to understanding how occupational structures evolve and deducing therefrom the most appropriate training policies.
11. A bibliography of the main works dealing with the quantitative and qualitative analysis of manpower needs is given in Annex to this document.

C) ACCESS OF WOMEN

It may be noted that in many countries only small numbers of women enter engineering education, so that the engineering profession is being deprived of much potential talent. National traditions and social factors are very important, but it is clear that an engineering career is not now inherently unsuitable for women, and that they can become fully and fruitfully employed as engineers.

To encourage the entry of women to engineering education and to ensure that their work is appropriate to their talents, it is necessary to make a major effort to break down the existing barriers, real or imaginary. Guidance of girl students at the secondary school level is an important need, and the engineering societies and industry should be more active in promoting the attractions of an engineering career for women and in persuading employers to change their present attitudes.

QUALIFICATIONS AND TRAINING NOMENCLATURE (NQF)

1. AIMS

This method of analysis - "Qualifications and Training Nomenclature" or NQF as it is termed - should enable us to reply to two questions in respect of technicians, technologists and engineers: "Who does what?", and "How many do what?".

2. METHODS

2.1 In an economic sector or occupational branch covered by the analysis, we propose first of all to establish a job analysis card (cf. 4.2 and 4.3) for each listed occupation, describing the nature of the work, and, secondly, the educational qualifications required to perform it. So that these cards may be used in studying the matching up of employment needs and educational requirements, they should be quantified, i.e. the number of similar jobs must be shown on each card. Likewise, if different training processes involving varying formal education requirements lead to the same function, which is generally the case, we must be able to record the normal <sup>(\*)</sup> proportion of these various processes.

2.2 We propose, next, to classify these cards according to eight job levels by reference to a standard table (cf. 3.3). This superposed arrangement, transferred to an organization chart (cf. 4.1) should reveal the categories of qualification and the commencing jobs in each category.

2.3 In order to make use of these cards in the education sector, we should make a second regrouping in each occupational branch, based this time on formal education levels, giving, in the form of a recapitulative table (cf. 4.4) the total number of jobs in the branch corresponding to each formal education level.

2.4 Lastly, so as better to place the survey, once analysed, in its context, it should be accompanied by a brief description of the technological and economic situation in the branch considered.

3. REFERENCE TERMINOLOGY

3.1 Analysis of the function

Analysis of the function contains a description of three elements :

work performed;  
degree of independence;  
responsibility.

31.1 Work performed

Brief description of the main tasks or duties, showing the nature and extent of the theoretical and practical knowledge required, as well as constraints arising from the environment or from respect for standards of hygiene, security, etc.

(\*)

The so-called "normal" proportion, in our view, might not necessarily be the one existing precisely at present, but the proportion both "desirable and feasible in the near future".

### 31.2 Degree of independence

Scope for personal initiative, extent to which work is performed under supervision and in conjunction with others.

### 31.3 Responsibility

Nature and extent of intervention in the direction, co-ordination or management of one or of several economic or human groups.

## 3.2 Job levels

32.1 Each analysis of the function should be classified, on the basis of its three elements (work performed, degree of independence and responsibility), at an occupational level by reference to a standard table containing 8 levels represented by the figures 1 to 8.

32.2 In the following reference table, levels 4, 5 and 6 are subdivided into two separate categories according to whether the corresponding posts are predominantly technical (abbreviation - TEC) or predominantly managerial (abbreviation - MAN).

32.3 We have, thus, the following standard job levels:

- 1
- 2
- 3
- 4 TEC and 4 MAN
- 5 TEC and 5 MAN
- 6 TEC and 6 MAN
- 7
- 8

## 3.3 Standard table of the eight job levels

For the purposes of this paper, detailed description of levels 1 to 3 are omitted since they concern skills no higher than those of qualified workers.

Level 4 (two categories according to the predominant characteristic)

MAN - predominantly managerial

TEC - predominantly technical

| Predominant characteristic | Work performed                                                                                                                                                                                                                        | Degree of independence                                                                                                                                                                                                            | Responsibility                                                                       | Examples                                                                                                           |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| MAN                        | Exercise of a trade or profession requiring basic knowledge at least equal to that required at level 3 for the same category of qualification, but including responsibility for directing a team of lower-level workers.              | Ability to distribute the means made available to the team on the basis of the standards demanded, the aim assigned and the directions received from his immediate chief.                                                         | Limited to the direction of the team, within the scope of the instructions received. | Charge hand.                                                                                                       |
| TEC                        | Exercise of a trade or profession requiring basic knowledge at least equal to that demanded at level 3 for the same category of qualification, but also requiring partial knowledge in other categories and higher operational skill. | Ability to adapt the available means to the standards demanded, and to the aim assigned, according to the instructions received from his immediate chief and within the limits of personal initiative in performance of the work. | None or limited to helping a lower level employee.                                   | Highly qualified worker; very specialized timberman (mines); bookkeeper; agricultural machine repairer. Draftsman. |

Level 5 (two categories according to the predominant characteristic)

MAN - predominantly managerial

TEC - predominantly technical

| Predominant characteristic | Work performed                                                                                                                                                                                                                                       | Degree of independence                                                                                                                                                                | Responsibility                                                                                                                                                                                                               | Examples                                                                      |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| MAN                        | Requires thorough knowledge of several trades, includes responsibility for the direction and organization of the work of a group of lower-level operatives and demands grasp of management and cost problems. Ability to train personnel supervised. | On the basis of the instructions received, fixing of precise targets for the personnel under his direction, in liaison with the other services. Responsibility for achieving targets. | To plan, organize, train, motivate, co-ordinate and supervise the activities of lower-level personnel placed under his direction, within the scope of the instructions received and according to previously defined methods. | Overman (Mining), foreman, supervisor, head of unit.                          |
| TEC                        | Exercise of a simple technique(1) or part of a more complex technique.                                                                                                                                                                               | Responsibility for interpretation of the instructions or information received for the practical application of the appropriate technique, either individually or in a group.          | None, or limited to helping a lower-level employee.                                                                                                                                                                          | Technician (chemical), designer-draftsman, technical assistant (engineering). |

- (1) Definition of "technique" in relation to "trade" or "discipline": technique requires a whole range of more or less extensive knowledge in categories of qualification other than the category in question, which is in addition to the knowledge required at the immediately lower level and a necessary adjunct in respect of the function performed. The extent and nature of this complementary knowledge determine the degree of complexity of the technique.

Level 6 (two categories according to the predominant characteristic)

MAN - predominantly managerial

TEC - predominantly technical

| Predominant characteristic | Work performed                                                                                                                                                             | Degree of independence                                                                                                                                                                             | Responsibility                                                                                                                                                                                                                         | Examples                                                           |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| MAN                        | Requires thorough knowledge of a simple technique (or part of a complex technique) and involves managerial responsibility for a service within a unit or a larger complex. | On the basis of the instructions received, fixing of precise targets for the personnel under his direction in liaison with the other services. Responsibility for achieving targets.               | To plan, organize, train, motivate, co-ordinate and supervise the activities of the lower-level personnel placed under his direction, within the scope of the instructions received and in accordance with previously defined methods. | Works manager.                                                     |
| TEC                        | Thorough knowledge of a complex technique.                                                                                                                                 | Responsibility for interpretation of instructions or information received from a higher level for the practical application of a complex technique, either individually or as a member of a group. | None or limited to helping lower-level personnel.                                                                                                                                                                                      | Higher production technician, junior engineer (design department). |

Level 7:

Work performed: carrying out of functions involving very extensive knowledge in various technical areas, coupled generally with managerial responsibilities for units forming part of larger complexes.

Degree of independence: on the basis of the decisions taken at a higher level, ensuring the practical application overall of a well-defined general policy, by means of appropriate directives and planned, precise action.

Responsibility: in accordance with the established policy, to carry out forward planning, co-ordinating and supervisory functions in respect of a production unit.

Example: production manager.

Level 8:

Work performed: complex functions in the management of a group of units.

Degree of independence: has to take largely independent decisions implying very considerable responsibility as regards forward planning, organization, co-ordination and supervision, at the level of a whole enterprise that has a marked influence on the external milieu.

Responsibility: maximal.

Example: director of the enterprise.

4. SURVEY DOCUMENTS

4.1 An organization chart of occupations should be established prior to the survey for each economic sector reviewed and should show every job title. It is preferable to review and re-adjust it, if necessary, after the survey.

4.2 Model of the job analysis sheet (see following page).

# 4.2 MODEL OF THE JOB ANALYSIS SHEET

|                                                           |                            |                                                                                                               |                                                                                                                          |
|-----------------------------------------------------------|----------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Occupation: _____                                         |                            | Analysis of the function                                                                                      | Training requirements                                                                                                    |
| Number of Jobs (N): _____                                 |                            | <u>Work performed:</u> _____<br>_____<br>_____<br>_____<br>_____<br>_____<br>_____<br>_____<br>_____<br>_____ | <u>Skills:</u> _____<br>_____<br>_____                                                                                   |
| <u>Category of Qualification:</u> _____<br>_____<br>_____ |                            |                                                                                                               | <u>Training (3 or more cases)</u><br>(a) Formal education requirements: _____<br>Experience: _____<br>Number (n1): _____ |
| Level                                                     | Predominant Characteristic |                                                                                                               | (b) Formal education requirements: _____<br>Experience: _____<br>Number (n2): _____                                      |
|                                                           |                            |                                                                                                               | (c) Formal education requirements: _____<br>Experience: _____<br>Number (n3): _____                                      |
| Recapitulation:<br>(N = n1 + n2 + n3)                     |                            | <u>Independence:</u> _____<br>_____<br>_____                                                                  |                                                                                                                          |
|                                                           |                            | <u>Responsibility:</u> _____<br>_____<br>_____<br>_____<br>_____<br>_____                                     |                                                                                                                          |

#### 4.3 Explanation of the job analysis sheet content

43.1 Occupation: indicate the title normally used.

43.2 Number of jobs (N): indicate the number of persons in this occupation.

43.3 Category of qualification: indicate the title of the "Category of Qualification", i.e. a set of functions requiring qualifications with common or specific features. These functions are generally superposed in rank order and are combined in the manufacture of a single object or the provision of a single type of service.

43.4 Level: refer to the standard table of the eight job levels:  
examples 1, 2.....8.

43.5 Predominant characteristic: refer to the standard table of the eight job levels: indicate MAN or TEC in the case of levels 4, 5 or 6 only.

43.6 Skills: indicate if particular skills are required for performing the work.

43.7 Training: persons with different training may have the same employment. What is more, it is generally desirable to have, at the same occupational level, persons with different training characteristics. For some this may be initial employment in preparation for a higher post, but it is a good thing for them to meet, within their occupation, experienced persons for whom their employment represents the normal culmination of their training and career. Diversity, where this exists, in the make-up of an occupation, should be pinpointed, by indicating how many persons (n1) fulfil (or should fulfil in the near future) such formal education and experience requirements; similar information should be provided in respect of others (n2) and any remaining (n3) category (if applicable) where formal education levels differ. Obviously we should have:

$$n1 + n2 + n3 = N$$

43.8 Formal education requirements: a classification by educational level should be established on the basis of the educational system of the country in question to which easy reference may be made under the "formal education requirements" head. The following table(1) is suitable for general application and could therefore facilitate international comparison.

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(1) Excerpt from Annex III.1, p. 82 of the report on "besoins en main-d'oeuvre et développement éducatif en Algérie" by J. Tamar, A. Revesz and C. Bertrand, June 1973 (Unesco, Series No. 2982/RMO.RD/EP Paris, October 1973).

| <u>Educational level</u> | <u>Definition</u>                                                                                                                                                                                     |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Level 1                  | Personnel without qualifications or not requiring any training. <sup>(1)</sup>                                                                                                                        |
| Level 2                  | Elementary education, plus one or two years of training mainly through practice.                                                                                                                      |
| Level 3                  | Elementary education, plus 2 to 4 years of training, or middle-level education plus 1 to 2 years of training, i.e. a total of 9 to 11 years.                                                          |
| Level 4                  | Complete secondary education (or equivalent) usually including a technical or vocational training component, or middle-level education, plus 3 or 4 years of training i.e. a total of 11 to 13 years. |
| Level 5                  | Complete secondary education, plus 2 or 3 years of higher training, i.e. a total of 14 or 15 years.                                                                                                   |
| Level 6                  | Complete higher education; i.e. 16 years or more.                                                                                                                                                     |

43.9 Experience: indicate the number of years required in lower-level posts before access is open to the job analysed.

#### 4.4 Model recapitulative table for a given occupational branch

For each occupation the figures (n1, n2, n3) under the "training" head are placed at the ad hoc level in a classification table based on the six formal educational requirement levels (cf. 43.8); a proposed model is set out on the next page. If the study is concentrated at the technician, technologist and engineer level, education classifications numbers 1 to 3 may be merged. The level of each job is indicated, in brackets, following its title, i.e. from 1 to 8, and, where applicable, its predominant characteristic (TEC or MAN) (for levels 4 to 6).

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(1) Training is taken in the sense of "technical training".

MODEL RECAPITULATIVE TABLE FOR AN OCCUPATIONAL BRANCH

| Category of<br>Level of<br>qualifi-<br>cation<br>of for-<br>mal educa-<br>tional<br>requirements | A<br><br>Nber                                                | B<br><br>Nber                             | C<br><br>Nber                                                     | <br><br>Nber |
|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------|--------------|
| 1 to 3<br>Total: 600                                                                             | 100                                                          | 200                                       | 300                                                               |              |
| 4                                                                                                | Job a<br>(4 TEC) 25<br>Job b<br>(5 MAN) 20                   | Job h<br>(5 MAN) 30                       | Job k<br>(5 TEC) 10<br>Job l<br>(6 MAN) 30<br>Job m<br>(6 TEC) 20 |              |
| Total: 135                                                                                       | 45                                                           | 30                                        | 60                                                                |              |
| 5                                                                                                | Job c<br>(5 TEC) 5<br>Job d<br>(6 MAN) 10<br>Job e<br>(7) 10 | Job i<br>(6 MAN) 10<br>Job j<br>(6 TEC) 5 | Job n<br>(6 TEC) 40<br>Job o<br>(7) 20                            |              |
| Total: 100                                                                                       | 25                                                           | 15                                        | 60                                                                |              |
| 6                                                                                                | Job f<br>(7) 20<br>Job g<br>(8) 10                           |                                           | Job p<br>(7) 10                                                   |              |
| Total 40                                                                                         | 30                                                           | 0                                         | 10                                                                |              |
| SUM TOTAL: 875                                                                                   | 200                                                          | 245                                       | 430                                                               |              |

## 5. METHOD OF OPERATION

- 5.1 The active participation of all sectors concerned by the analysis should be sought (industrial producers, production executives, Government, teachers and trainers).
- 5.2 It should be borne in mind that an exhaustive survey may not be indispensable. A well chosen sampling could well provide the results expected.
- 5.3 Economic and technological conditions of each industrial branch considered should be specified in connection with the survey. If a particular industrial branch involves units where technology and organization are very different, it may be preferable to present the results in a separate way for the particular units.

FIRST PRACTICAL METHOD  
PRAGMATIC METHOD FOR FORECASTING QUANTITATIVE  
REQUIREMENTS IN RESPECT OF ENGINEERS AND TECHNICIANS

The problem

The determination of requirements in respect of engineers and technicians forms part of the more general problem of determining the number and nature of personnel of all kinds required for a given economy.

Requirements at the national level depend in turn on the overall requirements of each sector of activity for personnel with varied qualifications and at all levels of responsibility. Overall requirements are also closely related to the number of working hours forecast for the achievement of production goals. Production capacity is dependent not only on investment but also on the supply of personnel, which is itself governed by the career guidance and training policy followed by those responsible for the education system during the preceding period.

Thus the wheel comes full circle, proving that the problem to be dealt with cannot be dissociated from its wider context, since the values to be determined (the number of engineers and technicians) form part of an organic equilibrium which involves all the factors in the economy.

The various points to be taken into consideration cannot be studied in isolation from each other, nor can they be set out regardless of order. An assessment of the number of engineers and technicians presupposes a preliminary study of the development prospects for the economy under consideration, which necessarily includes employment prospects for different types of personnel.

The formulation of a career guidance and training policy is preceded by market research. Working out an education system before conducting market research would be comparable to putting the roof on a building before having a clear idea of the layout of its walls and supporting structures. Thus the order of the stages to be followed is:

1. Forecasting the labour market, which presupposes a preliminary knowledge (or voluntarist determination) of the prospects for development of the economy.
2. Guiding young people towards specific types of training, in the light of the openings indicated by research into the labour market.
3. Formulating a training policy based on the data yielded by market research and on the diversity of the aptitudes and aspirations of young people. It is at this stage that teaching curricula and methods should be studied.

Forecasting the employment market for the various types and levels of training is thus the first task to be carried out. For this purpose the use of a simple model, such as the one described below, produces results which are a useful guide to the educational planner.

The three stages:

The process falls into three stages as follows:

- (a) Determination of the present distribution of engineers and technicians among the various sectors of activity, resulting in Table A below.
- (b) A study of probable trends (or desirable trends if, as is frequently the case, one is concerned with an economy which is to a certain degree planned) in the economic and socio-occupational situation between the present date and the date for which the forecast is being made (five or ten years hence).
- (c) Using the foregoing two elements, a determination of requirements in respect of engineers and technicians five or ten years hence.

A. Present distribution of technical personnel

This distribution should be indicated in a form which makes it possible to bring out requirements.

For simplicity's sake, only engineers will be dealt with here; the case of the technicians can be dealt with in exactly the same way. Engineers should be divided up, by individual specialization, among the main sectors of the economy. In defining these sectors, which should not exceed ten in all, reference should be made to the work of the economic planning services.

The next stage is to group together engineers into families, taking as the criterion their main activity.

Lastly, Table A should be drawn up as follows:

| Main<br>sectors of<br>activity       | Families of<br>engineers | Agricultural<br>engineers | Mechanical<br>engineers | Electrical<br>engineers | Chemical<br>engineers | General<br>purpose | Total |
|--------------------------------------|--------------------------|---------------------------|-------------------------|-------------------------|-----------------------|--------------------|-------|
|                                      |                          |                           |                         |                         |                       |                    |       |
| 1. Agriculture                       |                          |                           |                         |                         |                       |                    |       |
| 2. Chemistry                         |                          |                           |                         |                         |                       |                    |       |
| 3. Public Works                      |                          |                           |                         |                         |                       |                    |       |
| 4. Mechanical<br>Engineering<br>etc. |                          |                           |                         |                         |                       |                    |       |
| <b>TOTAL</b>                         |                          |                           |                         |                         |                       |                    |       |

Thus the figures in each line group together the various types of engineers working in a given sector: for instance in the chemistry sector will be found not only chemical engineers but also mechanical engineers, electrical engineers, general purpose engineers, etc.

The totals contained in the right-hand column will make it possible to relate the total number of engineers to the various major economic activities, i.e. to establish forecasts by sector.

We thus have a model which contains:

an educational dimension: families of engineers;

an economic dimension: sectors of activity.

B. Assessment of the economic and socio-occupational situation between the present time and the end of the forecast period

Making use of existing economic planning studies, one should here study in detail:

(a) trends of economic activity during the forecast period;

(b) probable employment trends;

(c) probable personnel requirements.

(a) Trends of economic activity

For each sector the growth rate during the preceding three to four years will be used to extrapolate the growth rate for subsequent years, though not in a linear, purely mechanical manner; account should also be taken of information regarding the factors likely to produce momentum, or to curb growth, in specific sectors. This study should be carried out in close association with the economic planning services. Discussions should also take place with professional organizations and the directors of a few enterprises in each sector.

(b) Employment trends

When the growth rate (negative or positive) has been determined for each sector it will be used to deduce probable employment trends, i.e. trends in the length of the working week and the overall number of personnel employed.

Generally speaking, an increase in production results in a relatively smaller increase in working hours. The saving thus achieved goes to raising productivity. This varies from one sector to another, and frequently from one enterprise to another.

This study should be carried out using periodical employment statistics and also the surveys conducted by certain trade union or professional organizations.

The production increase can as a first approximation be attributed to a corresponding increase in the number of hours worked, which may be obtained partly by increasing the length of the working week (if circumstances are favourable) or by increasing the numbers of those employed.

(c) Trends in personnel requirements

Here a study is made of the structure of the working population and probable changes therein. The necessary data should be sought from the occupational statistics; failing this it will be necessary to conduct a survey for each sector in order to find the relationship between the total numbers employed in each sector and the grand total.

Account should also be taken of comparative growth rates as between total manpower and the various categories of personnel (in certain fast-expanding industries the number of engineers and technicians increases more rapidly than the total manpower). Here an extrapolation should be made from the trends observed over the last five to six years.

C. Prospective requirements in respect of engineers and technicians

This is the vital stage of the study, since training policy will necessarily be based on the prospective requirements at different times ahead.

It will be necessary to examine successively:

- (a) requirements, by sector;
- (b) requirements, by type of training;
- (c) the design of the forecasting model with reference to various times ahead;
- (d) the balancing of requirements and availabilities at each such time.

(a) Overall requirements, by sector

The scientific and technological trends which we are now witnessing result in a more rapid increase in the number of professional staff and technicians in relation to the workforce as a whole. Leading sectors and enterprises have an average density of engineers and technicians which is greater than that of the economy as a whole. Also to be noted is the frequent appointment of technically-trained staff to professional posts previously occupied by those having no technical training, in particular to posts of a commercial and administrative nature.

The effect of these replacements in the past should be studied; in particular, one should identify the engineers who have opted for commercial and administrative careers. If, for example, in the past the replacement coefficient was  $P\%$ , and the increase in the total number of professional staff and engineers was  $C\%$ , the increase for the engineers alone will be  $C\% \times P\%$ .

(b) Requirements, by type of training

The  $P\% \times C\%$  increase in requirements in respect of engineers in one sector breaks down in different ways depending on the type of training, i.e. by "families of engineers". One must therefore conduct an analysis by "family". This will be done bearing in mind both the social and the economic points of view.

From the social standpoint, a study will be made of vacancy statistics for each sector, including the breakdown in respect of each sub-sector. A comparison will be made for each sector between the distribution of engineers as a whole among the different sub-sectors and the distribution of those who have graduated in the last three or four years, in order to pinpoint apparent changes in the nature of the requirements; the findings will be compared with the views of a number of directors of enterprises.

From the economic standpoint, the study will begin by carrying out the following check: two sub-sectors in the same sector making the same contribution to gross domestic product (GDP), which have the same density of engineers and the same development prospects, should increase the number of engineers they employ on the same pro rata basis. However, if chemical engineers predominate in one sub-sector and electrical engineers in the other, the same growth rate will be reflected in different increases, depending on the specialization: growth in the first sub-sector will result in an increase in the number of chemical engineers and in the second in the number of electrical engineers.

Thus an exhaustive study of structures and probable trends, on the basis of information compiled from the sub-sectors concerned and from planning bodies, produces, for a single percentage increase for all engineers employed in a given sector, different percentages depending on the type of specialized qualification required.

In this way, if the number of engineers in the various families actually in employment today is known, it is possible to determine the corresponding numbers at various times ahead.

(c) Designing the forecasting model with reference to various times ahead, and the calculation of requirements

Once the study has been carried out for each sector in Table A, it will be possible to deduce Tables  $B_1$ ,  $B_2$ , and  $B_3$ , which give the breakdown of requirements in respect of engineers five or ten years hence.

TABLE B

| Families of engineers<br>Sector of the economy | Agricultural engineers | Mechanical engineers | Electrical engineers | Chemical engineers | General purpose | Total |
|------------------------------------------------|------------------------|----------------------|----------------------|--------------------|-----------------|-------|
| 1. Agriculture                                 |                        |                      |                      |                    |                 |       |
| 2. Chemistry                                   |                        |                      |                      |                    |                 |       |
| 3. Public Works                                |                        |                      |                      |                    |                 |       |
| 4. Mechanical engineering etc....              |                        |                      |                      |                    |                 |       |
| TOTAL                                          |                        | 30                   |                      |                    |                 |       |

(d) Balancing needs and resources at varying lengths of time ahead

This study should be from a dual standpoint:

1. An overall point of view, taking into account  
the length of the training process;  
the output of graduates.
2. A structural point of view, taking into account the needs which are specific to each family of engineers.

A student beginning his engineering course usually graduates at the end of five years. If we allow an extra year for possible delays or military service, it is only at the end of six years that it will be known whether the number of first-year admissions corresponded to the desired number. Hence, on the assumption that all necessary measures are taken to rectify an imbalance (a surplus or shortage of engineers), the first effects of these measures will not be felt until at least six years later.

Where a surplus exists, emigration abroad, which is always a theoretical possibility, would not in itself be adequate to restore the balance. We are then faced either with unemployment or with a number of engineers employed on tasks which correspond to neither their qualifications nor their desires, with all the consequences which such a situation may entail for both society and the individual.

This having been said, assessed needs are compared as follows with numbers available:

1. Take numbers currently available (Table A).
2. Deduct the number of engineers who will have left the profession before the future time in question.
3. Add the number of new graduates and the probable number of engineers who will have immigrated over the same period.

We thus obtain the surpluses or shortages for each family of engineers (or technicians). It is probable that the results will vary noticeably from one family of engineers to another, and that they will therefore have to be taken into account in deciding what measures are needed to rectify the situation.

It should be noted that the present tendency to stress basic training in the training of engineers does not do away with the need to forecast requirements by specialization. Like any other specialist, an engineer should have a thorough knowledge of his own field, and deserve to be called a good specialist in that particular field.

Training of a general nature, which is becoming more and more essential, will help him to keep abreast of progress achieved in his own special field and the neighbouring fields in which his fellow-workers are employed, and also to change from one special field to another if necessary, after a relatively short period of retraining. But the possibility of changing from one special field to another is not always the same; for instance it is easier for an agricultural engineer to become a chemical engineer than an electrical engineer. Hence general training is no substitute for training in the various special fields, and students should be guided during their courses to those branches where requirements are greater than elsewhere. Such guidance should be given on a continuous basis during training, which becomes more and more specialized towards the end of the course.

## SECOND PRACTICAL METHOD

## METHOD BASED ON THE PROJECTION OF OCCUPATIONAL COEFFICIENTS

It is assumed that the production target to be reached a given length of time ahead has been determined, both for the economy as a whole and for each of the main sectors. Such data should be supplied by the economic and social planning services of the country concerned.

The method consists of calculating the coefficients of occupational structure, i.e. the percentage of each type of worker in the total number employed in the sector or in the economy as a whole, using data contained in censuses carried out at different dates in the past.

We thus obtain the trends for these coefficients over a certain period, and these are projected to the end of the period covered by the forecast. The simplest method is to plot a graph with the dates of the earlier censuses and the end of the forecast period along the x-axis, and the occupational coefficients along the y-axis. There should be a graph for each occupation, i.e. one for engineers and another for technicians.

It is then possible to draw in by hand the curve which passes nearest to the points obtained, and to prolong it up to the end of the forecast period.

If greater accuracy is required, the method of least squares can be used to plot the line of best fit, which will actually be fairly close to the curve drawn in by hand.

Once the occupational coefficient for, say, engineers has been worked out in this way for the end of the forecast period, it is applied to the total numbers of manpower employed in each sector or in the economy as a whole, in order to obtain the number of engineers that will be needed at the end of the forecast period in order to achieve the production target.

This is a simple method involving extrapolation, but one which yields better results than if one simply extrapolated the number of engineers from the numbers recorded at the dates of the various census returns.

The reason is that in distinguishing between changes in the distribution of total employment by economic sectors on the one hand and changes in the occupational structure within these sectors on the other hand, one reduces to a certain extent the part played by pure extrapolation, by implicitly integrating the economic and technical factors on which the occupational breakdown of manpower requirements depends. This is confirmed by experience, as this method is widely used.

It is possible to refine the projection if one is not content with reading off the value of the coefficient from the graph: one can either use additional information on future trends, or take account of recent phenomena not incorporated in earlier returns, or again it is possible to weight the coefficients in the direction desired by the planner by means of a normative or voluntarist adjustment to the forecast. Thus one usually envisages several assumptions as regards possible trends, in order to obtain several assessments of needs at the end of the forecast period.

For example, it may be assumed that there will be no changes in the occupational structure between the last census and the future date in question. In this case, the number of engineers required will be influenced only by the total size of the labour force at that date.

A possible variant is to assume that the rate of change in the occupational structure will be greater than that yielded by extrapolation from past trends, since the economy is going through a boom phase or a major capital project (say the construction of a dam, which will suddenly increase the supply of power to the economy) is shortly going to produce results.

In conclusion, it should be noted that whatever the assumption, the most reliable results are obtained at the level of the economy as a whole, since developments in one sector offset those in another.

For educational planning this is no major drawback, since it is with a country as a whole that one is concerned when deciding to train a certain number of engineers on the basis of prospective requirements.

If further details are desired, what is of interest is not trends in the various sectors, but requirements in respect of various types of engineers, again for the country as a whole. In that case reference should be made - particularly for the purpose of calculating requirements in respect of technicians, whose specializations are narrower - to what has been said above in describing the first practical method.

THIRD PRACTICAL METHOD  
METHOD USING ECONOMIC INDICATORS

All countries now have more or less developed national accounting systems from which can be taken the past, present and (desired) future values of a number of economic indicators:

gross domestic product (GDP)  
GDP by economic sectors  
gross fixed capital formation per worker  
energy consumption  
productivity  
etc.

If it is desired to obtain rapidly an approximate figure for requirements in respect of engineers, the most convenient method is to choose GDP or per capita investment. Here again, the result obtained at the level of the economy as a whole is more satisfactory than for individual sectors.

After choosing the indicator to be used, its values are sought for different dates in the past, together with the value desired for the end of the forecast period.

The numbers of engineers employed throughout the country at the same dates are then taken from census returns or special surveys, and the correlation coefficient between the two variables calculated. This coefficient can be computed directly by machine.

Where the correlation is sufficiently satisfactory (correlation coefficient close to 1 - a coefficient as low as 0.80 is acceptable) this means that there is a relationship between the figures considered, and it is possible to plot a graph from which it will be sufficient to read off the figure for the number of engineers corresponding to the value of the indicator at the end of the forecast period.

It is a worthwhile precaution repeating this operation with two or three indicators (or establishing a multiple correlation, but we have seen that the results are not very satisfactory), and comparing the results obtained with those yielded by the projection method described above. Lastly, the results as a whole should be looked at with a critical eye before taking any decision.

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